Parameter Trade Studies For Coherent Lidar Wind Measurements of Wind from Space

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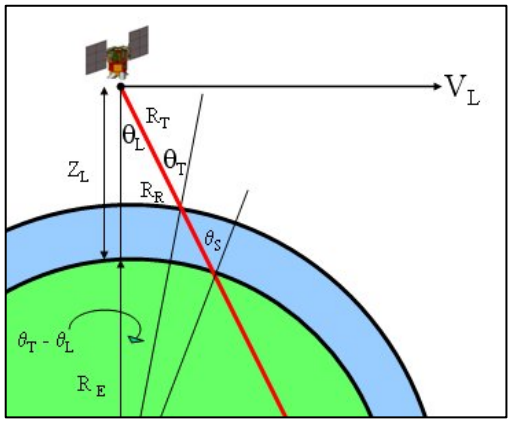
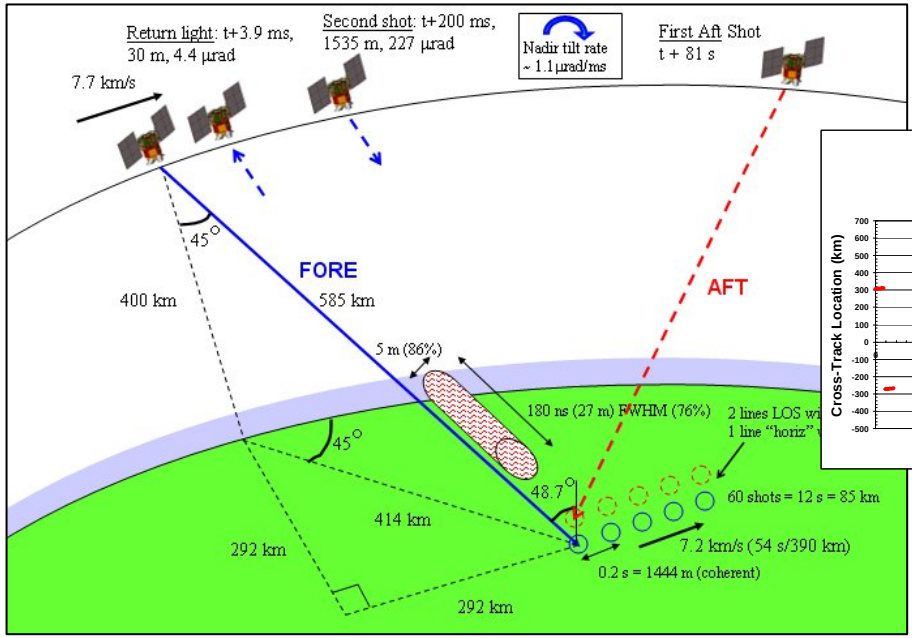
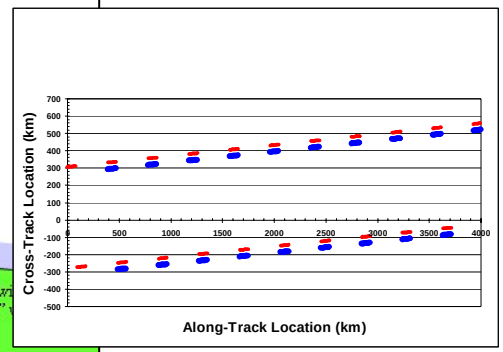
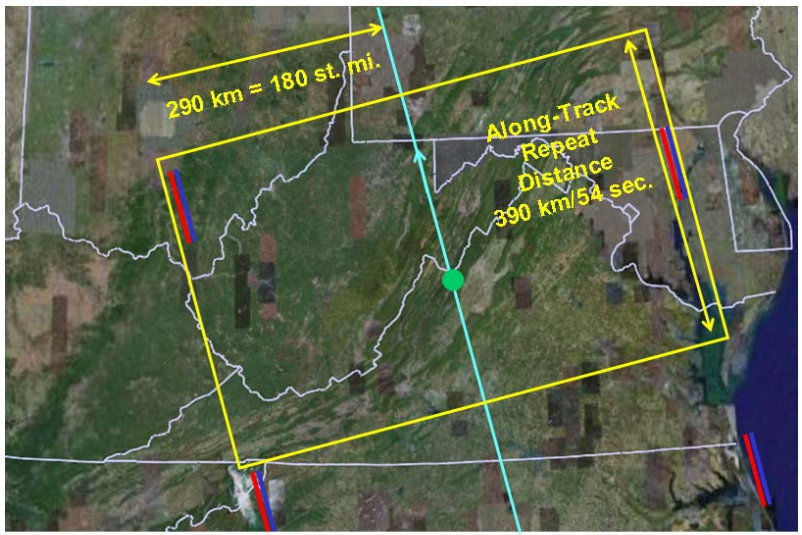
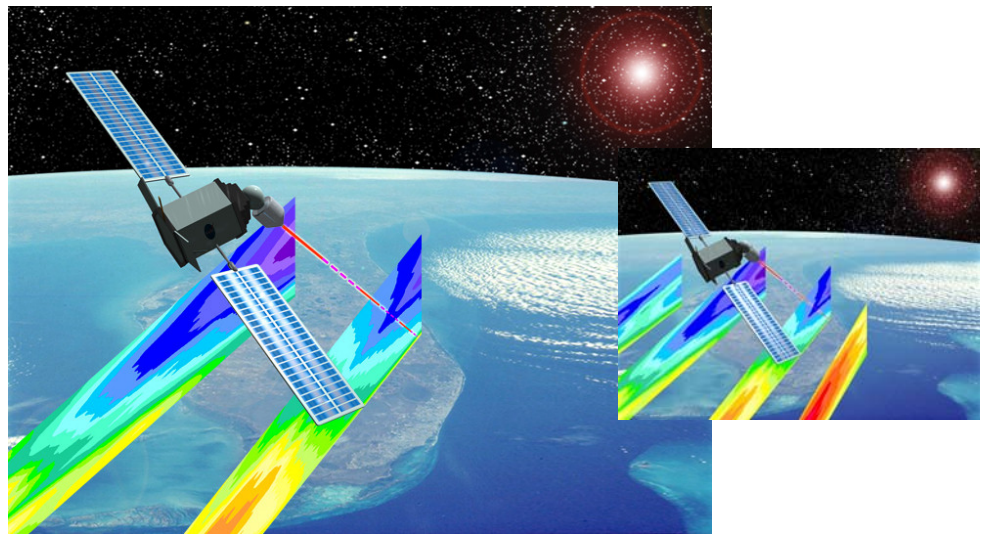
Global Wind Mission Concept









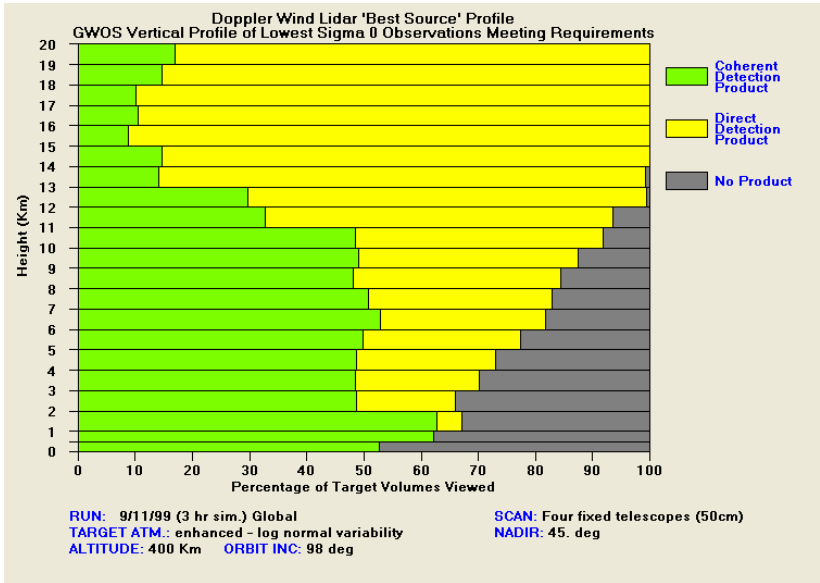


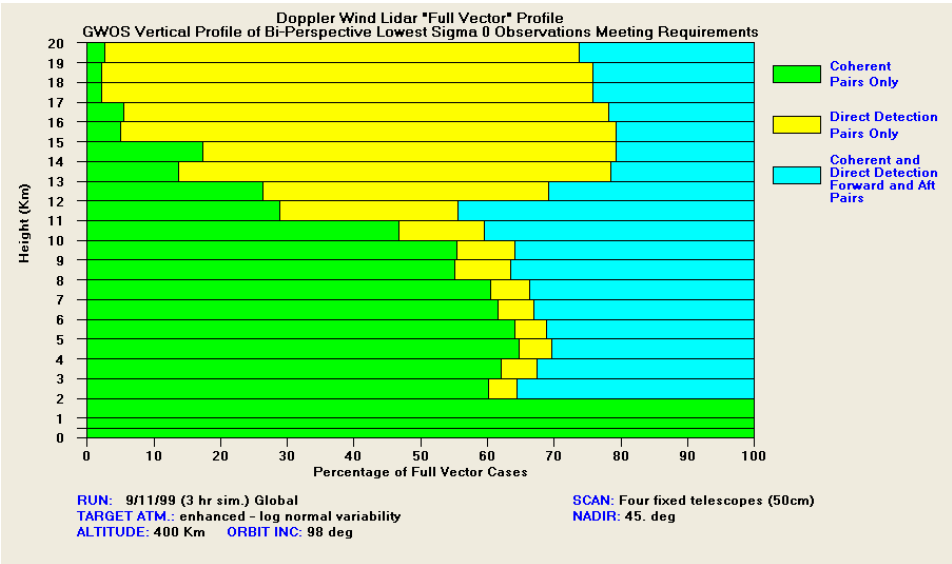
Hybrid Doppler Lidar Concept

Complementary Lidars Together Lower Total Mass, Power, Cost, Risk

Green represents percentage of sampled volumes when coherent subsystem provides the most accurate LOS measurement; **Yellow** is for direct detection; **Gray** is when neither system provides an observation that meets data requirements

GWOS with enhanced aerosol mode





When two perspectives are possible

Green: both perspectives from coherent system

Yellow: both perspectives from direct molecular

Blue: one perspective coherent, one perspective direct

GWOS Mission Study

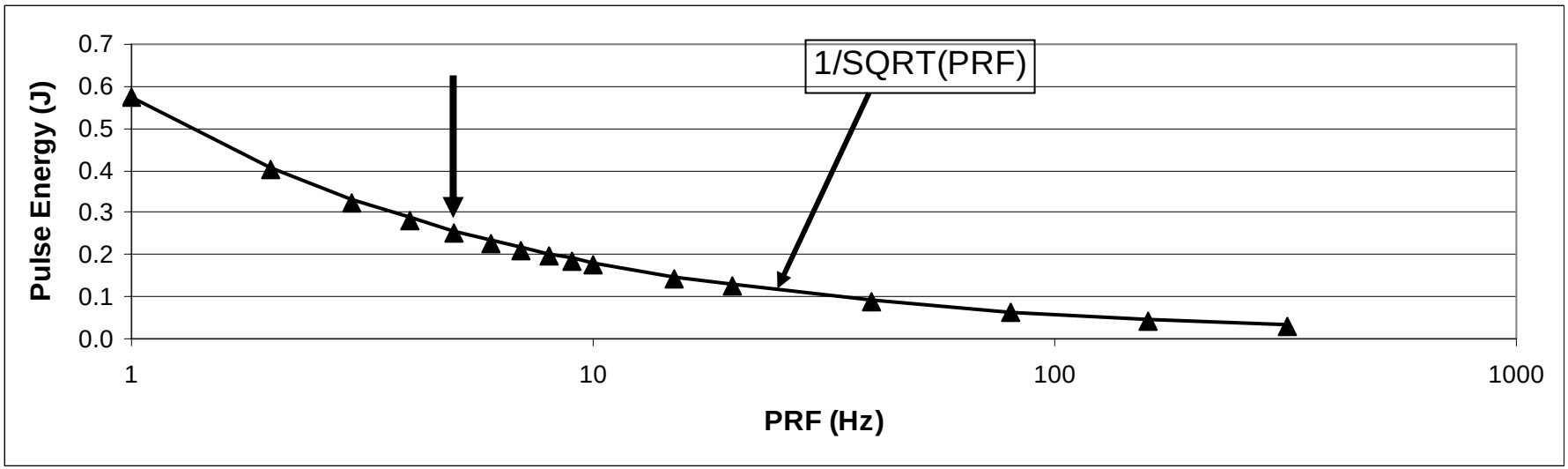
- Hybrid Doppler lidar
- 400 km, 45 deg nadir, 4 azimuth angles
- Coherent lidar:
  - 0.25 J, 5 Hz, 2.053 microns, 180 ns
  - 0.5 m receiver diameter
  - 60 shot accumulation attempted; 12 s; 85.2 km
  - Pattern repeat = 4 x (12 + 1.5) = 54 s = 390 km
- 1 m/s design 1-σ wind turbulence (broadens sig. spectrum)
- 0.5 m/s 1-s laser difference frequency knowledge error
- No vertical shear of horizontal wind velocity (always aligned with beam: broadens signal spectrum)
- Sampling/representativeness error = 0.62 m/s (85 km line in 100 km box)

Specific GWOS Operating Point For Trade Studies

- 5 km altitude wind measurement height
- Enhanced aerosol levels; $\beta = 2.75 \times 10^{-8}$ $m^{-1}sr^{-1}$
- Vertical resolution = 2000 m
- $\varphi = 4.5$ (# coherent photoelectrons per range gate per shot)
- 60 shots accumulation attempt
- Pr{good} = 0.95
- Lidar LOS velocity error = 1.5 m/s
- Lidar horizontal velocity error = 2.0 m/s
- With sampling error, total horizontal velocity error = 2.1 m/s

Pulse Energy vs. PRF

- Hold Pr{good} = 0.95
- Velocity error does not change

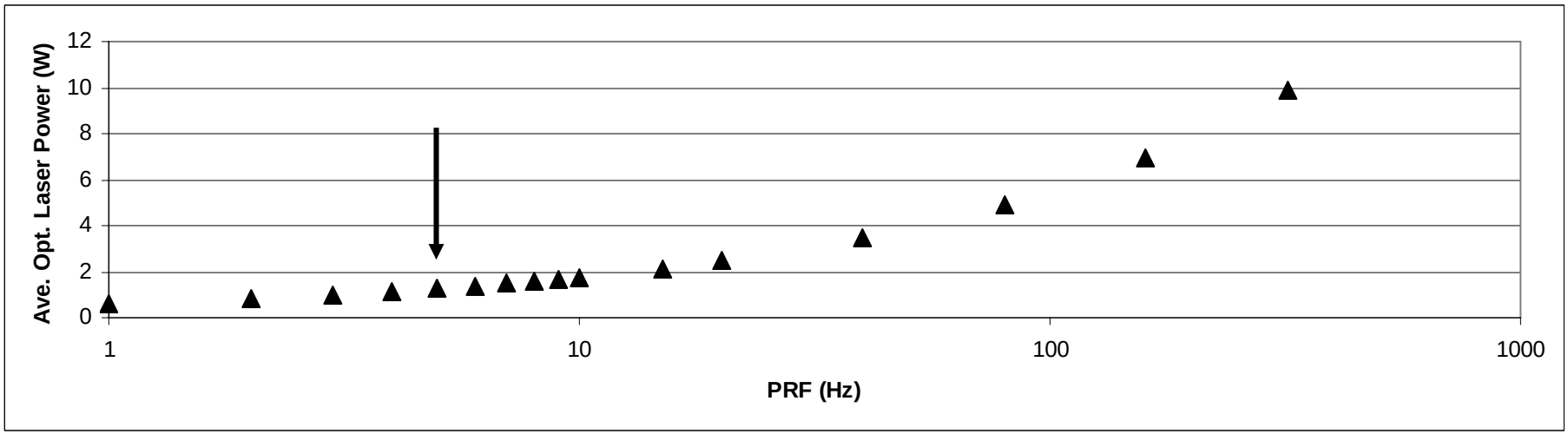


Favors higher PRF?

nominal operating point

Laser Power vs. PRF

- Hold Pr{good} = 0.95
- Velocity error does not change
- Laser Power = Energy x PRF

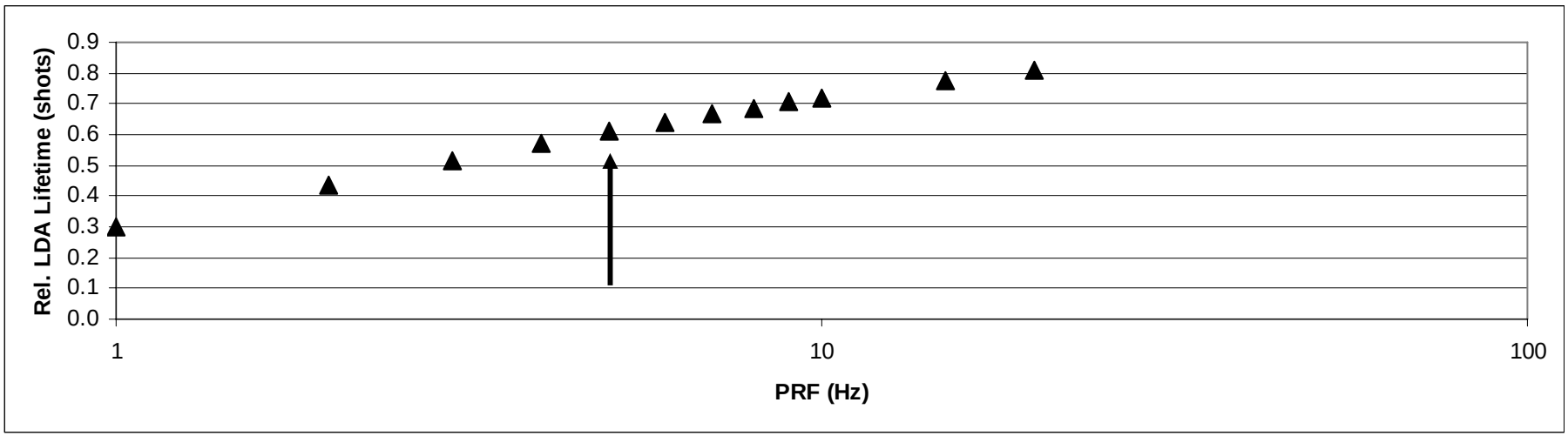


Favors lower PRF?

Relative LDA Lifetime vs. PRF

PRELIMINARY FOR TRADE CONCEPT ONLY

- Hold Pr{good} = 0.95
- Velocity error does not change
- LDA lifetime probably reflects laser lifetime

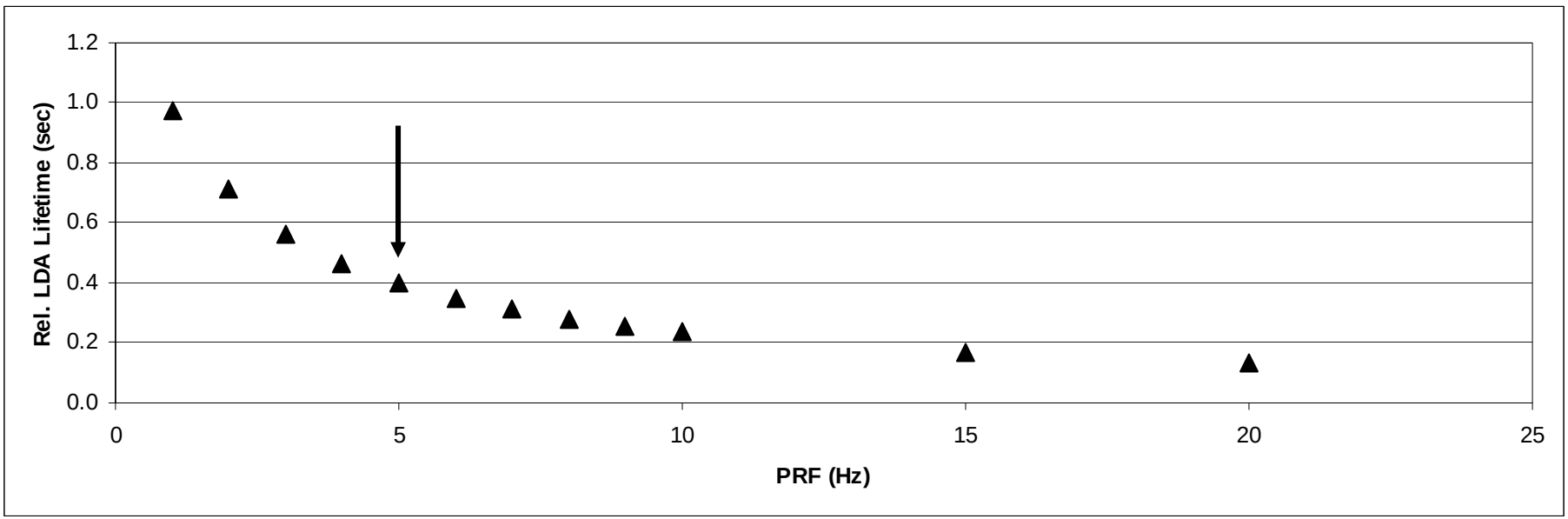


Favors higher PRF?

PRF vs. LDA Lifetime

PRELIMINARY FOR TRADE CONCEPT ONLY

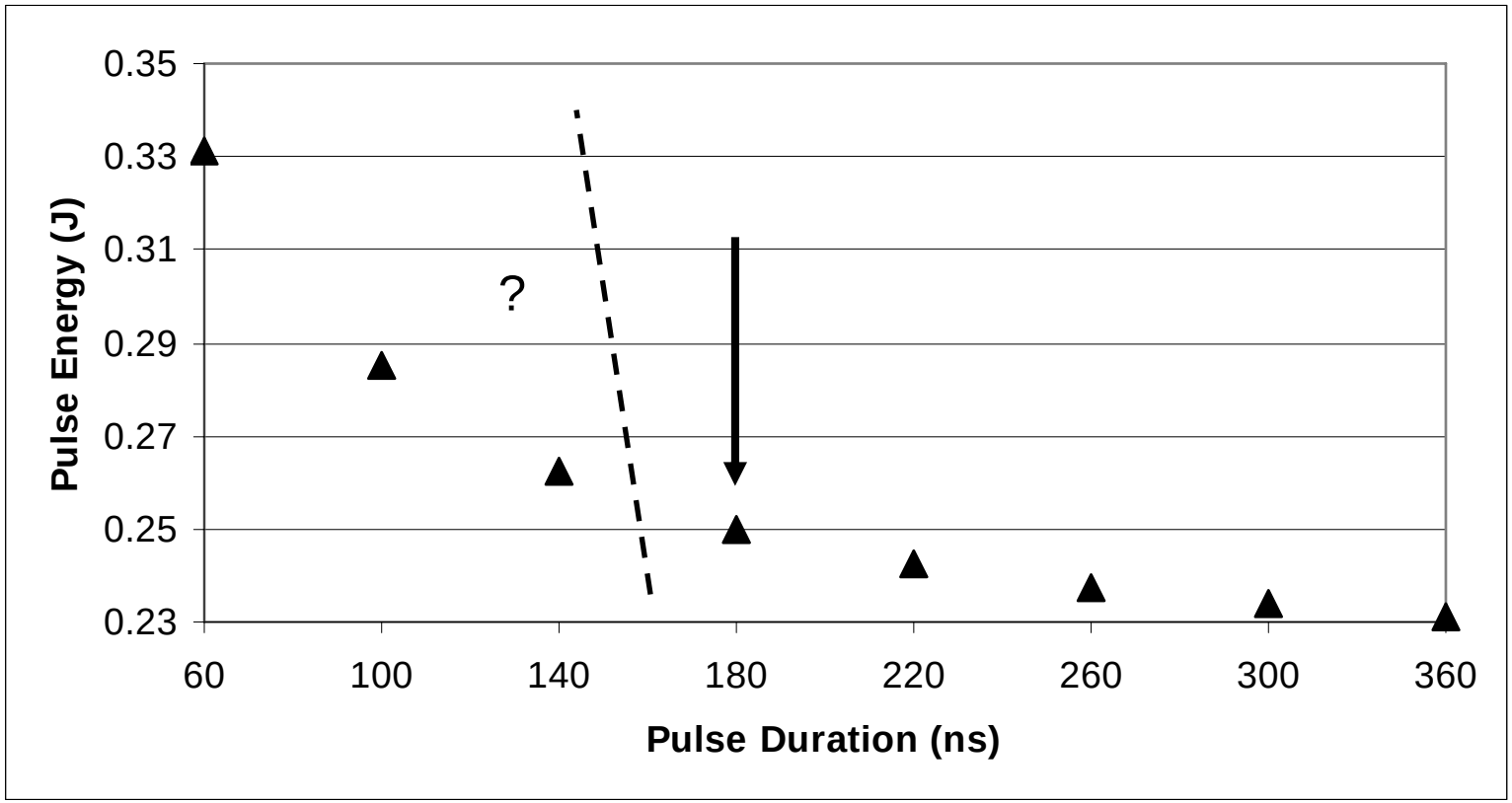
- Hold Pr{good} = 0.95
- Velocity error does not change
- Lifetime in **seconds** more important than lifetime in shots
  (seconds = shots/PRF)



Favors lower PRF?

Pulse Energy vs. Pulse Duration

- Hold Pr{good} = 0.95
- Velocity error fairly constant above 180 ns (5% bad estimates dominating)

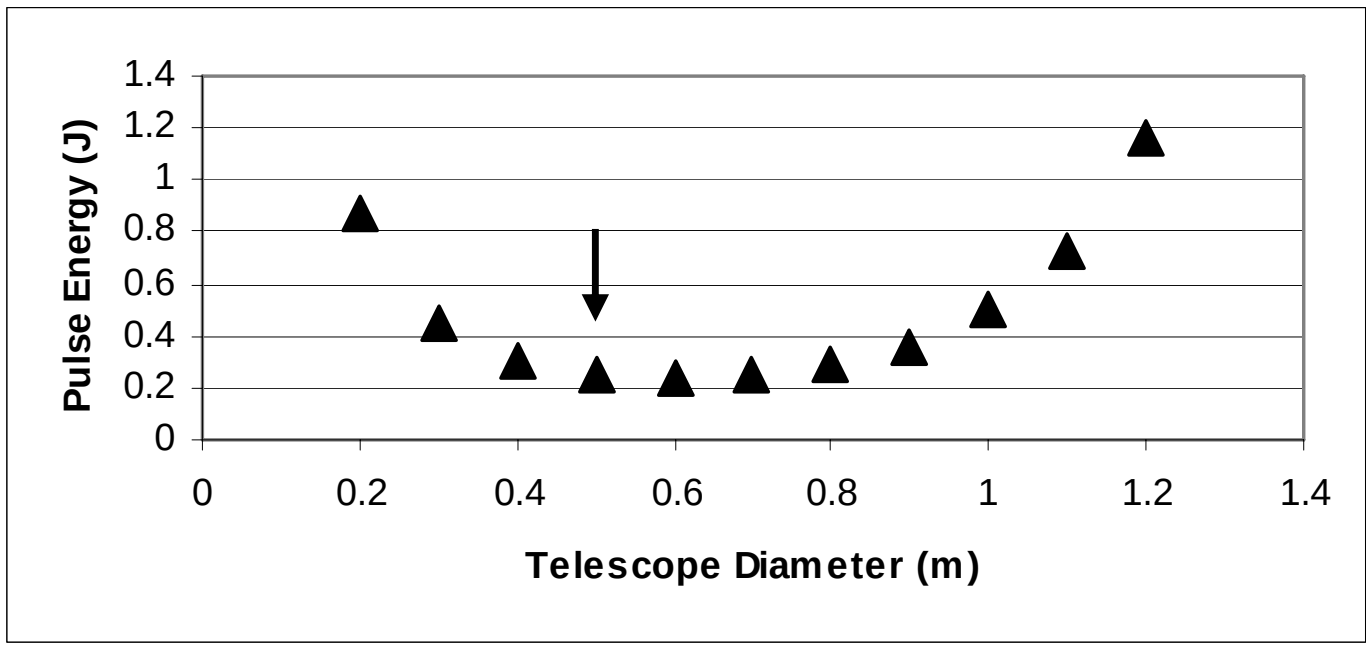


?

Outside the validated parameter range of the performance parameterization

Pulse Energy vs. Telescope Diameter

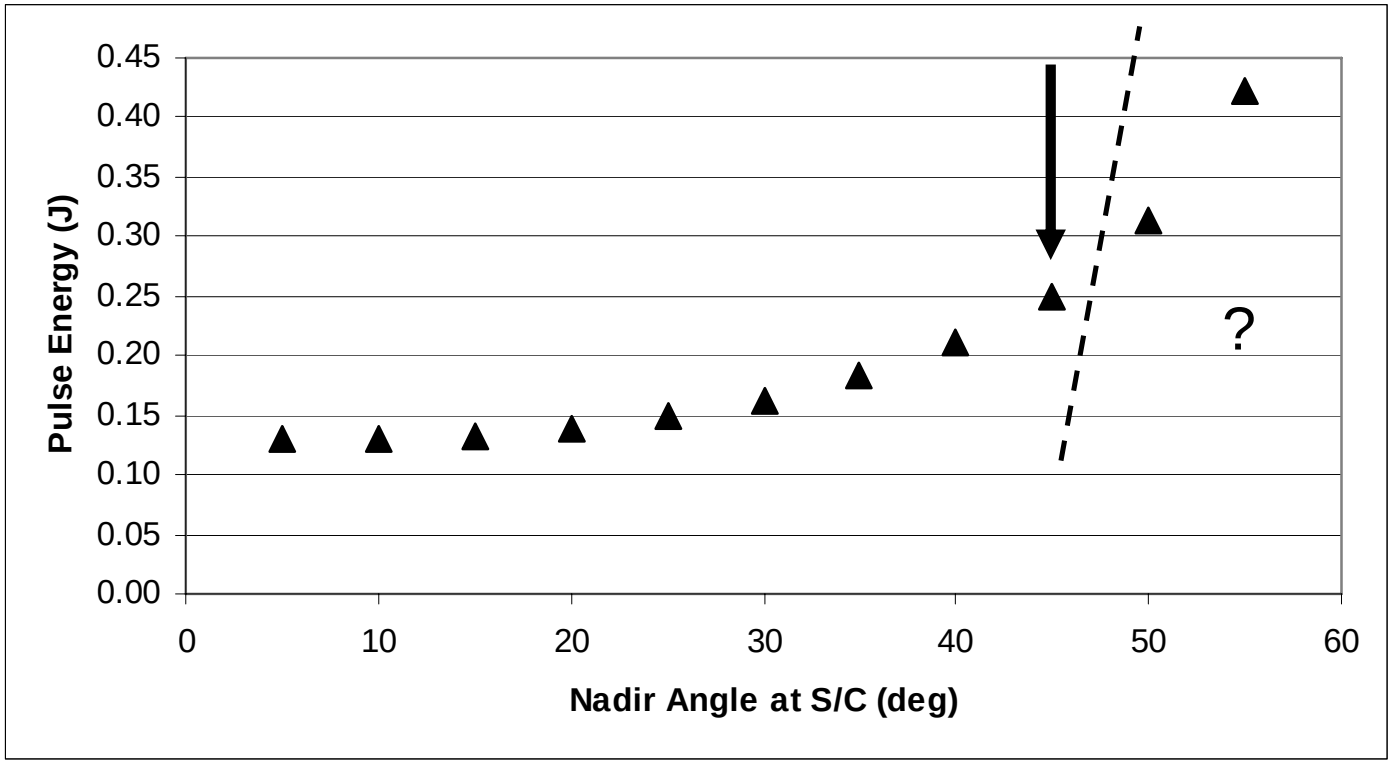
- Assume scanner does not reduce collection area
- Assume 1-σ transmit/receive misalignment angle fixed at 3.082 μrad
- Hold Pr{good} = 0.95 and velocity accuracy constant



- Larger diameters have more SNR loss for fixed misalignment angle

Pulse Energy vs. Nadir Angle

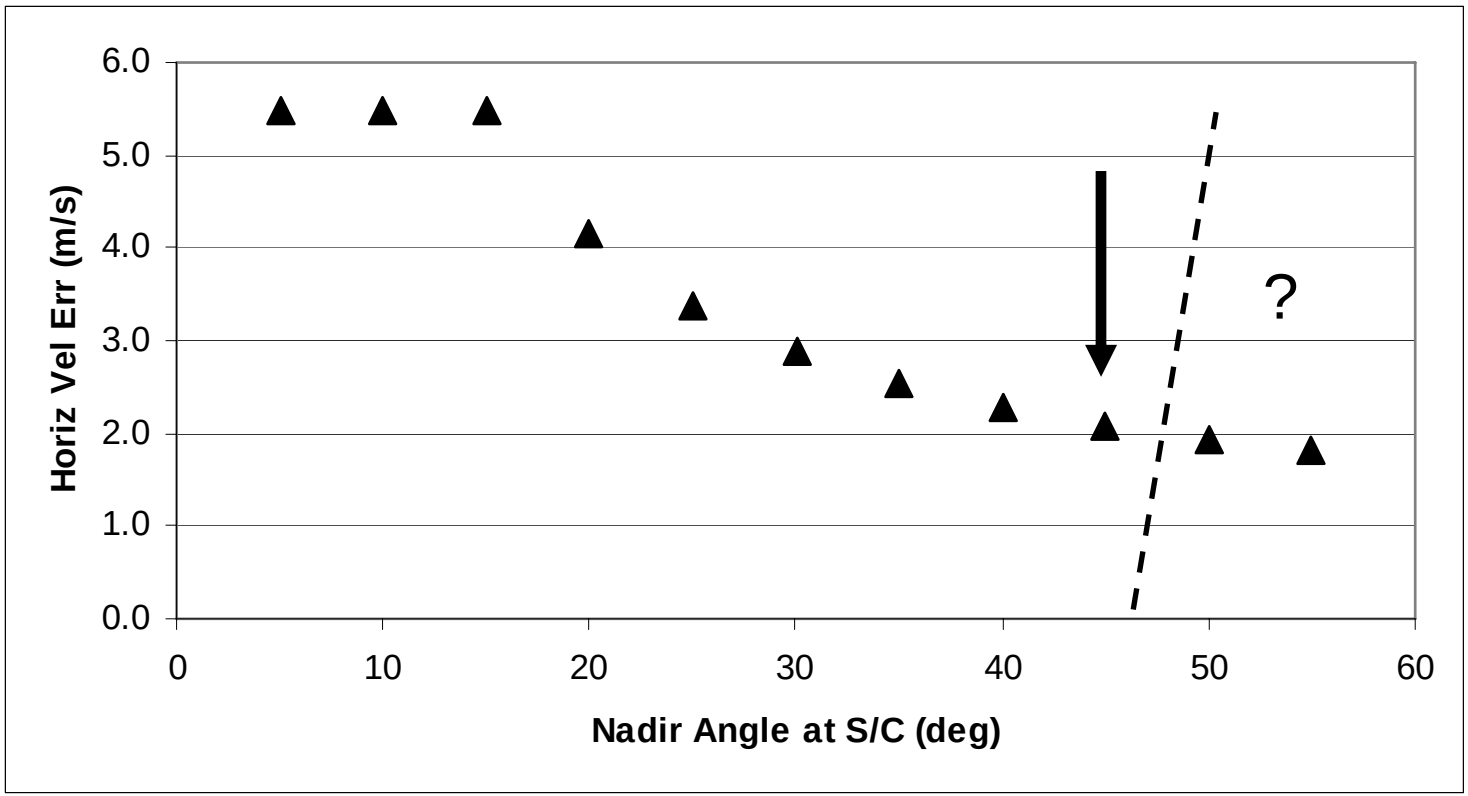
- Hold Pr{good} = 0.95
- Above 70 degrees misses the earth



- Spherical earth steepens the slope

Velocity Error vs. Nadir Angle

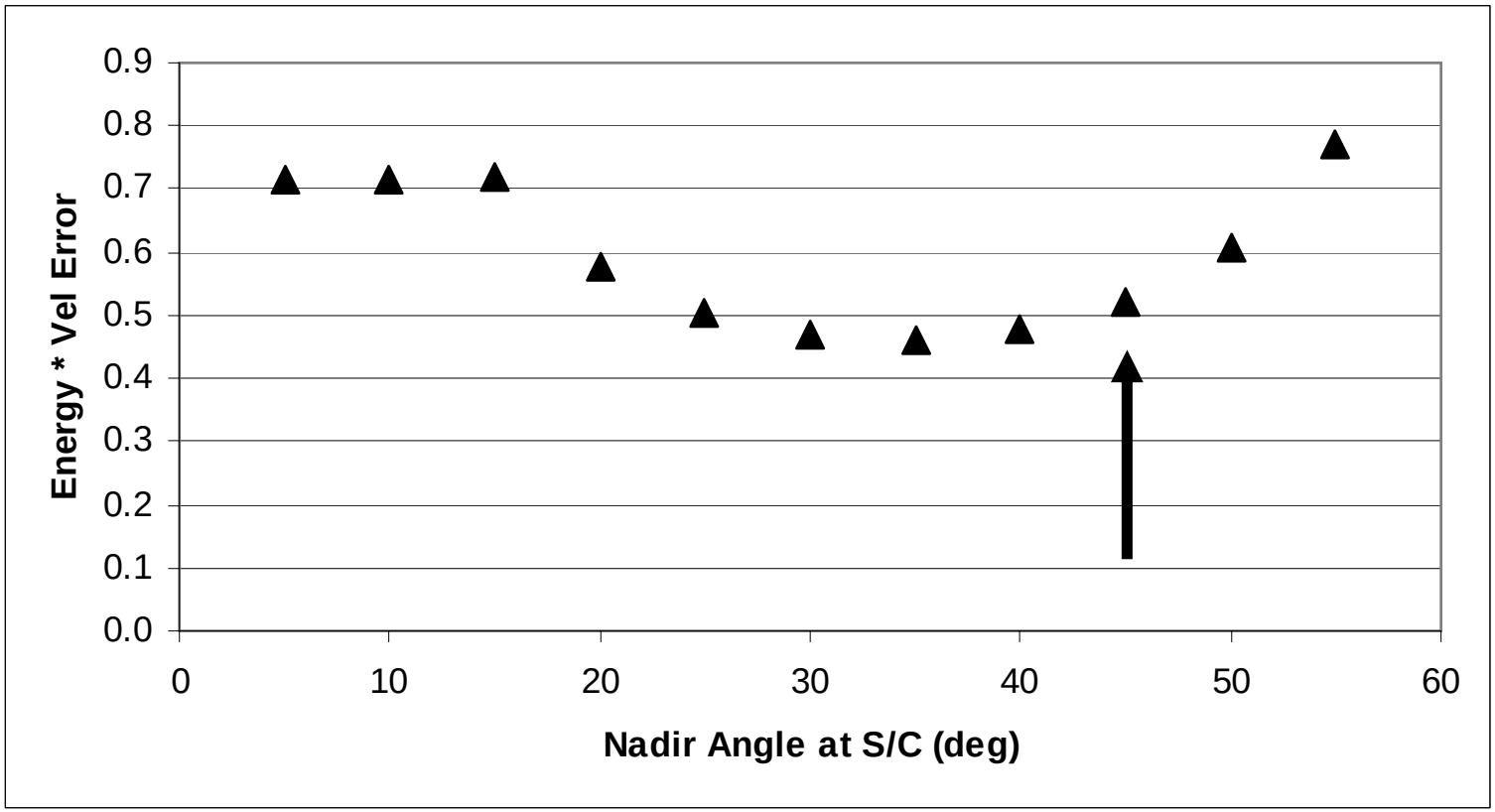
- Hold Pr{good} = 0.95
- Above 70 degrees misses the earth



- Laser beam more horizontal at larger nadir angles

Velocity Error x Pulse Energy vs. Nadir Angle

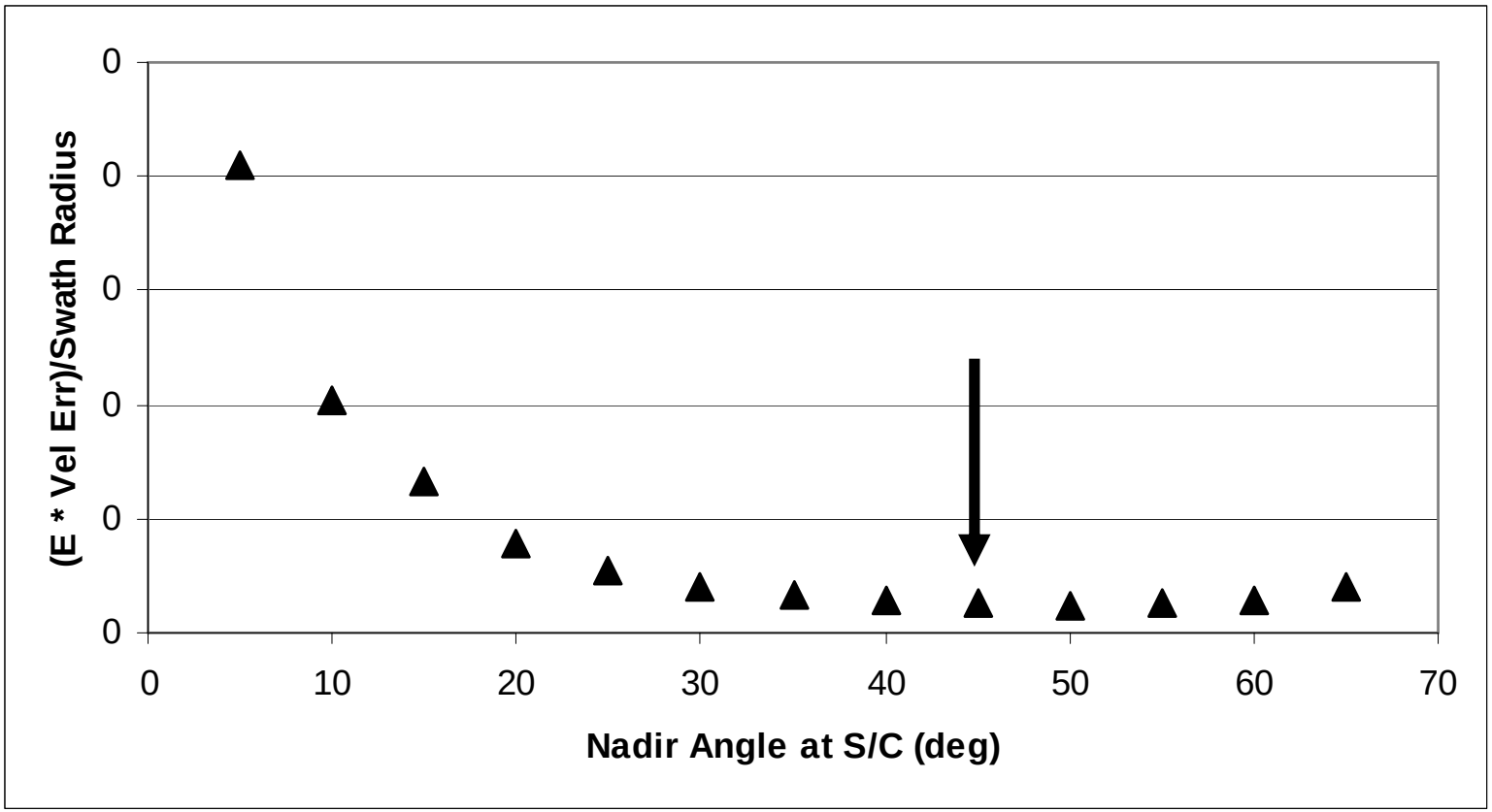
- Hold Pr{good} = 0.95
- Above 70 degrees misses the earth



- Broad optimum from 25 – 45 degrees

(Error x Energy)/Swath Radius vs. Nadir Angle

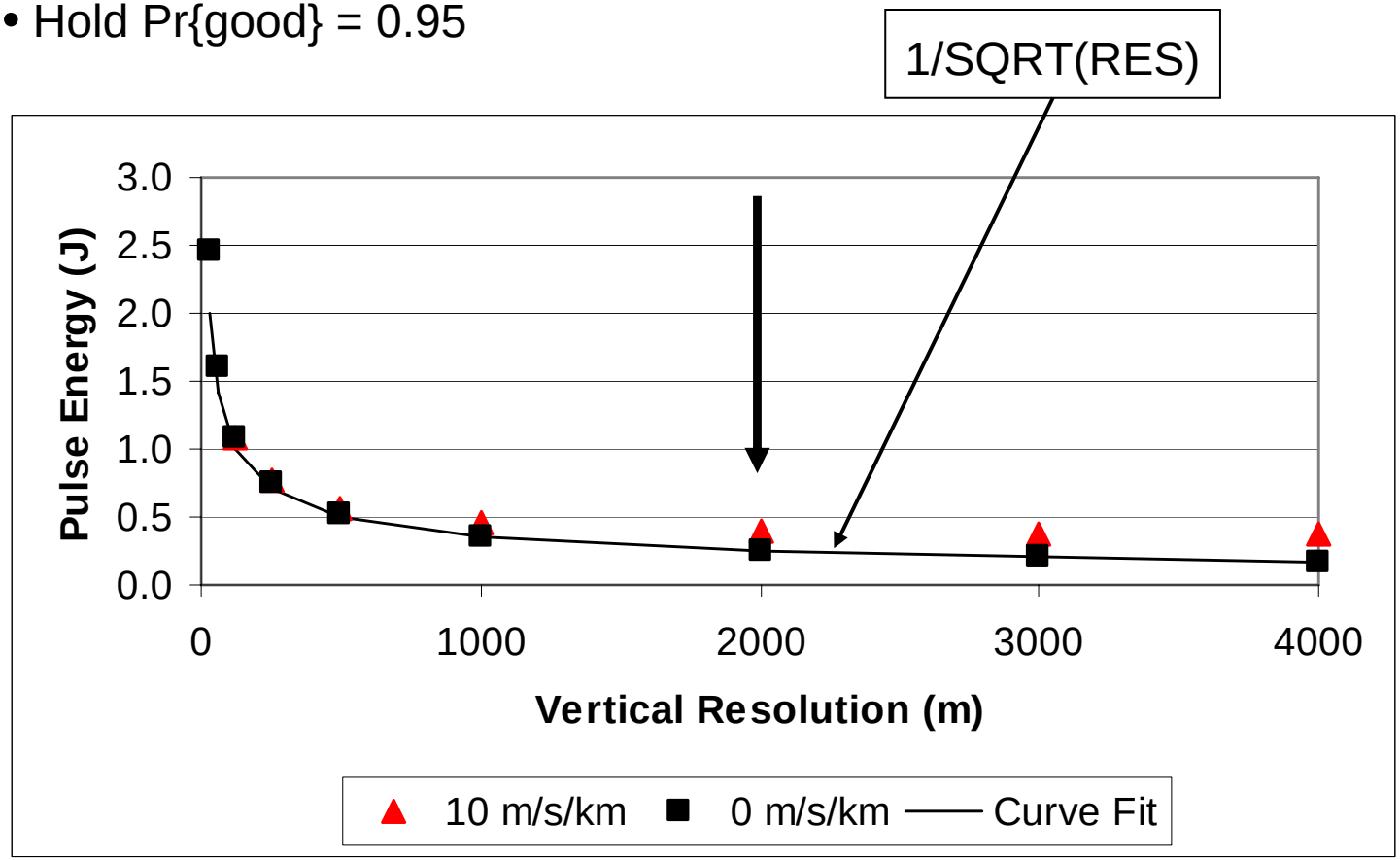
- Hold Pr{good} = 0.95
- Above 70 degrees misses the earth



- Broader optimum; what other figures of merit are there?

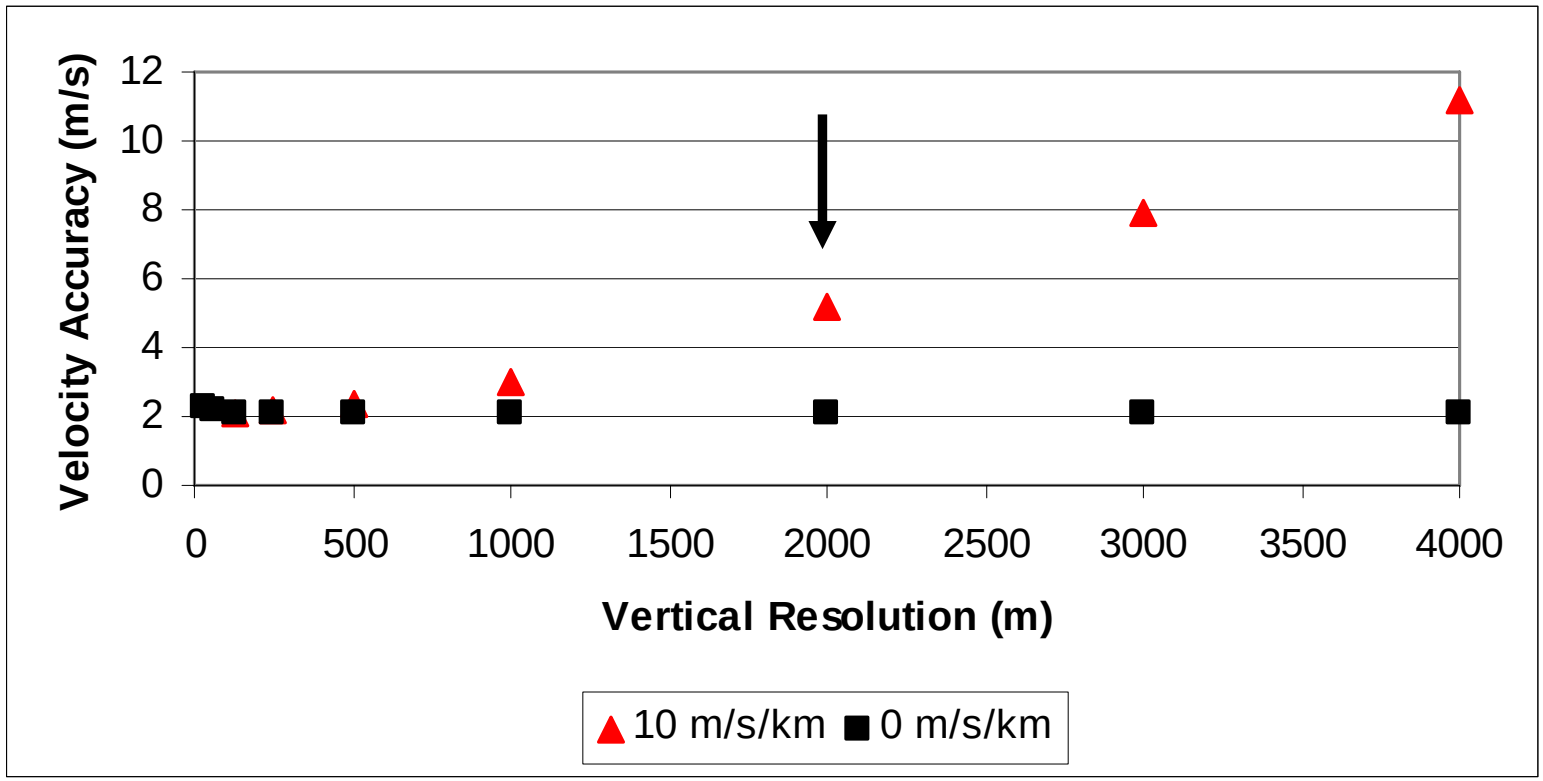
Pulse Energy vs. Vertical Resolution

- Hold Pr{good} = 0.95



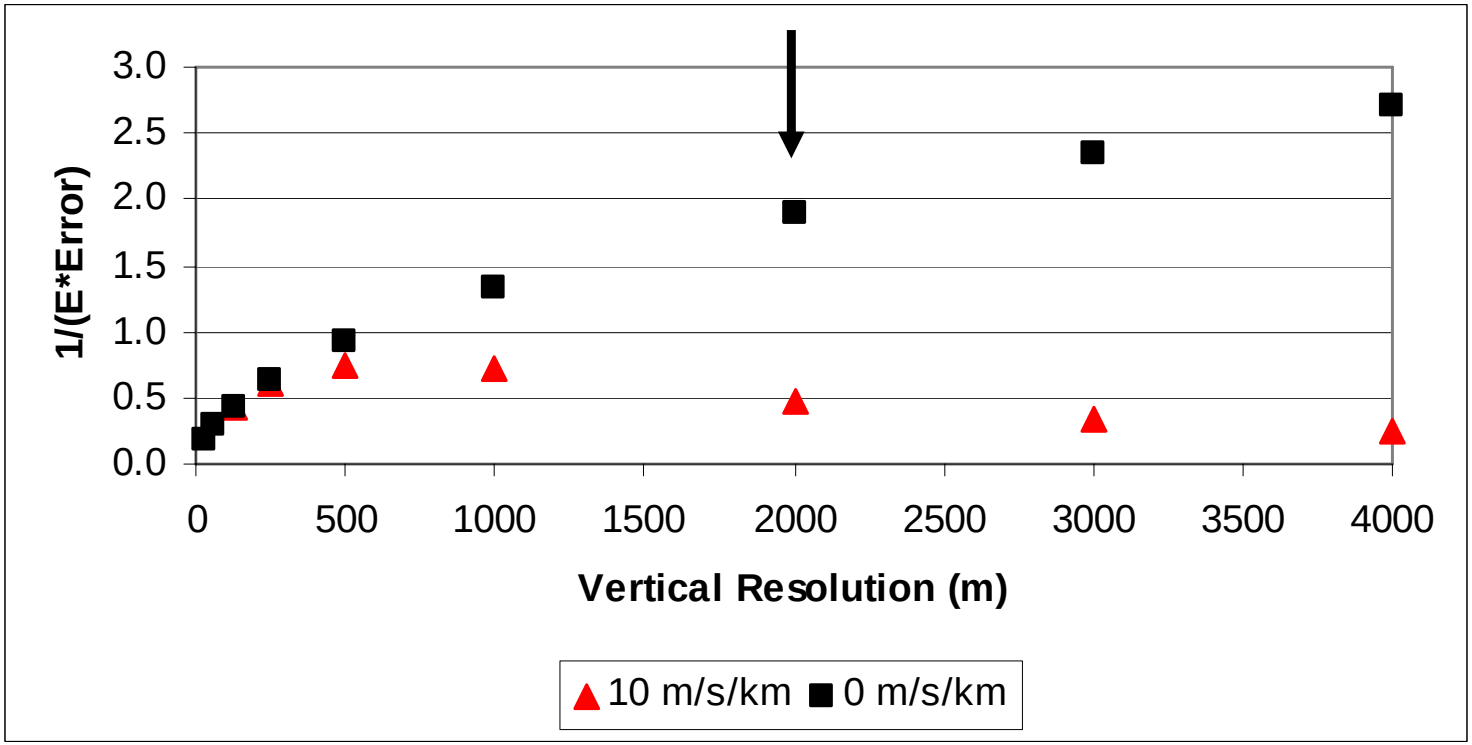
- Wind shear increases required pulse energy

Velocity Accuracy vs. Vertical Resolution



- Wind shear greatly increases velocity error
- Dilemma: pulse energy and velocity error favor oppositely

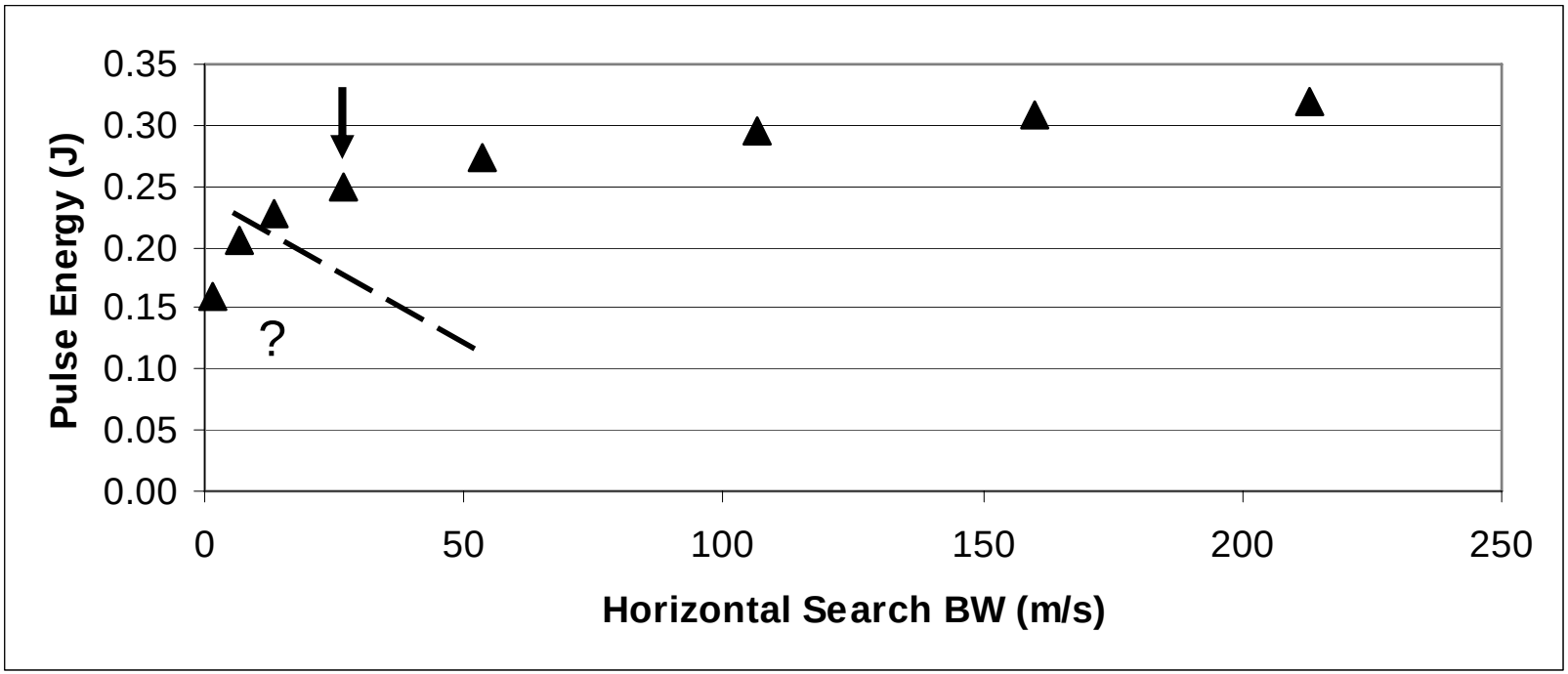
(Energy x Error)$^{-1}$ vs. Vertical Resolution



- Wind shear case has optimum vertical resolution

Pulse Energy vs. Velocity Search Bandwidth

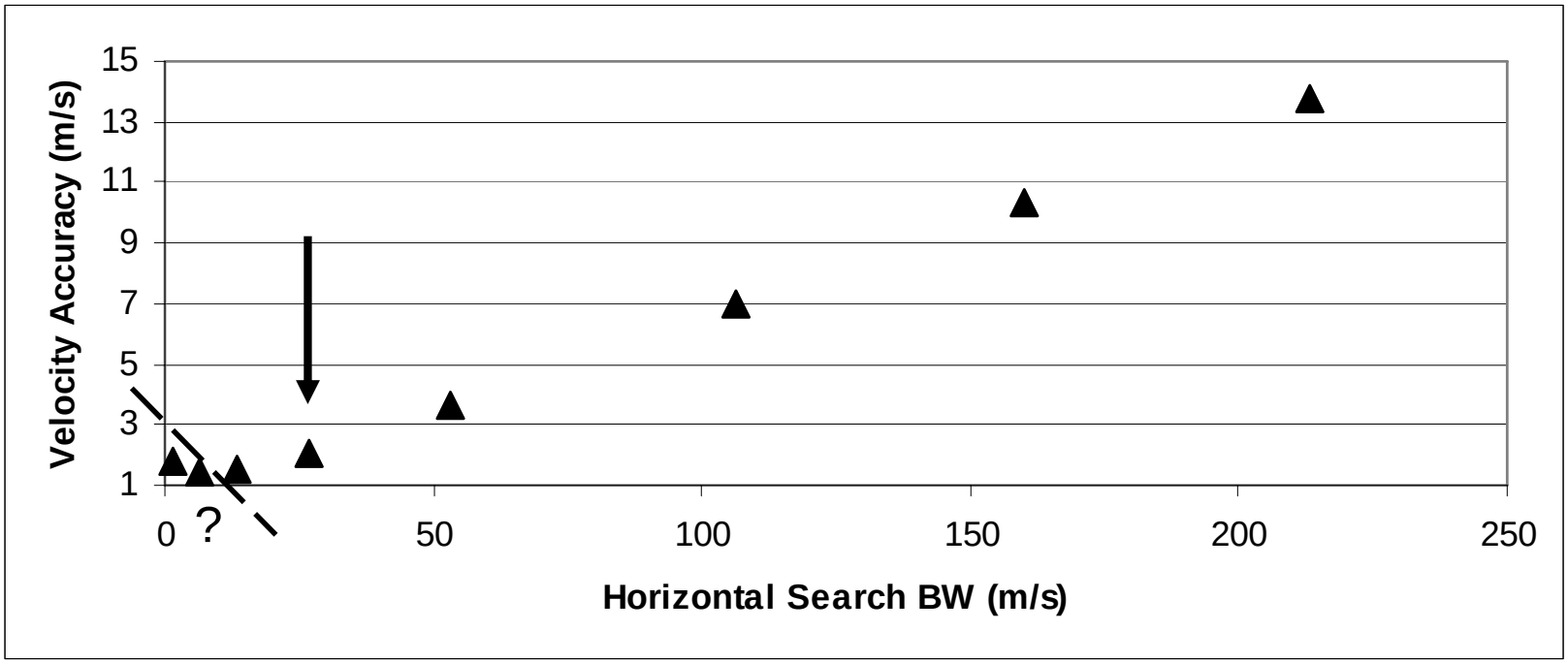
- Full search bandwidth in horizontal direction for last pass through the data
- Hold Pr{good} = 0.95



- Significant effect on pulse energy

Velocity Accuracy vs. Velocity Search Bandwidth

- Full search bandwidth in horizontal direction for last pass through the data
- Hold Pr{good} = 0.95



- Large effect on velocity error
- Bad wind estimates dominate error

Summary and Conclusions

- NASA LaRC computer simulation of global wind profiling coherent-detection Doppler lidar uses latest published theory
- Simulation permits parametric trade studies with choice of parameters held constant
- Tool should prove useful in mission design and guide to parameter goals for technology under development
- There are many more possible trades than are shown here
- Desire to incorporate optic component aberrations, laser beam intensity and phase description, and misalignment rigorously into theory

Back Up Slides